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Synergistic Effect of Functional Electrical Stimulation (FES) and Photobiomodulation in the Rehabilitation of a Patient with Lumbar Radiculopathy Due to Disc Herniation: Case Report

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Abstract

Lumbar disc herniation is characterized by chronic and persistent pain for more than 3 months, considered neuropathic pain, with sensory and motor changes causing sensitivity, consequently loss of muscle mass leading to decreased functionality, affecting the individual's quality of life. Treatment may be medication and/or rehabilitation, using physiotherapeutic resources, such as transcutaneous electrical nerve stimulation, functional electrical stimulation (FES) and photobiomodulation. FES generates a sequence of electrical stimuli in a coordinated and sequenced manner, triggering action potentials in intact peripheral nerves and activating muscle contractions. Photobiomodulation produces antioxidant action that protects the body against free radicals and anti-inflammatory activity with increased synthesis of ATP and others factors. Thus, the synergistic use of these resources was possible through equipment developed by the Institute of Physics of São Carlos, which allows irradiation perpendicular to the surface of the skin. The objective of this study was to evaluate the new device in a patient with lumbar radiculopathy due to disc herniation, with symptoms of pain and decreased strength. Visual analogue scale (pain), quality of life by Short Form 36 questionnaire, range of motion (goniometer), sensorimotor functions and degree of functional limitation (Fugl-Meyer Scale and Roland-Morris Disability Questionnaire) were used. Therefore, the synergistic effect of FES and photobiomodulation was directed both for the anatomical projection area of the vertebral segment and along the corresponding myotome in lumbar region (L5-S1 myotomes), for 30 minutes (10 sessions; twice a week). A decrease in low back pain, greater range of motion of the lumbar spine, improvement of sensorimotor function and improved quality of life leading to less functional disability. Therefore, the new equipment can be used in individuals with lumbar disc herniation, an innovative resource that can reduce the time of sessions and physical therapy treatment.

Keywords: Functional electrical stimulation (FES); Laser; Photobiomodulation; Pain; Lumbar disc herniation

Introduction

Low back pain is a globally prevalent problem, affecting 40% of the adult population, its origin is often unspecified, and it can encompass a spectrum of different types of pain, such as nociceptive, neuropathic, nociplastic and non-specific pain, which often overlap [1].

Although there is substantial heterogeneity among epidemiological studies of low back pain, leading to a limitation in the ability to compare and pool data, estimates of the one-year incidence of the first episode of low back pain have been found in the literature, approximately 80% of the population suffers an episode once in their lifetime [2],while the highest prevalence is among people aged 30 to 50, with a male to female ratio of 2:1 [3], in addition, approximately 95% of herniated discs occur in the lower lumbar region, specifically at the L4/L5 and L5/S1 levels. Hernias located above these levels are more common in people over 55 years of age [4,5].

Regarding clinical findings, the prevalence of nerve injuries associated with spinal pain stands out, characterized by radiculopathy and nerve compression caused mainly by herniated disc, with lumbar radiculopathy, known as sciatica being the most frequent [6,7].

In the study by Konstantinou and Dunn (1976), lumbar radiculopathy, known as sciatica, is the most frequent, ranging from 1.6% to 13.4%, and is most common between the ages of 45 and 64 [8].

It is important to highlight that the pain is chronic or persistent, generally lasting more than three months, and can manifest itself through sensations and symptoms [9].

Most reporting pain in the form of needles, burning sensations that may be accompanied by allodynia and hyperalgesia [10], considered neuropathic pain [11], with sensory and motor changes causing loss of functionality, sensitivity, muscle weakness and consequently loss of muscle mass, leading to functional incapacity and potentially affecting the individual's quality of life [12].

Treatment for low back pain with mechanical compression includes medication, surgery and rehabilitation. The main medications used in short-term treatment are non-steroidal anti-inflammatory drugs, opioids and topiramate. Surgery is a long-term option [13] considered

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by doctors. Rehabilitation, which can use manual and mechanical physiotherapeutic resources, such as transcutaneous electrical nerve stimulation, functional electrical stimulation (FES) and laser therapy (photobiomodulation), non-invasive methods that are safe and have few side effects [14,15].

Remembering that laser is a resource that has been widely used since 1957, is a resource widely used in health, its therapeutic effects are strongly associated with its antioxidant and anti-inflammatory actions and improvements in hemorheology [16].

Laser stimulation of red blood cells, promotes the synthesis of adenosine triphosphate (ATP), which is the main form of chemical energy in cells, and the antioxidant enzyme superoxide dismutase (SOD), responsible for neutralizing superoxide free radicals, compounds that are extremely harmful to the body [17]. This action contributes to the reduction of harmful oxidative processes in the body [18].

In addition to laser, another resource frequently used in clinical practice is surface electrical stimulation, a therapeutic modality that is less invasive and safer than pharmacological therapies or other resources to modulate spasticity [19], Transcutaneous electrical nerve stimulation (TENS) and functional electrical stimulation (FES) are two forms of surface electrical stimulation that are easy to use and can be easily administered by a therapist [20].

TENS is a commonly used therapeutic resource for pain control that exerts its actions by stimulating large-diameter mechanosensitive afferent nerve fibers in the skin [21]. The main hypothesis is that TENS can reduce spinal spasticity through mechanisms such as modulation of spinal inhibitory circuits, and/or activation of large-diameter afferents, and/or induction of central nervous system plasticity [22]. While TENS produces suppression of spasticity by activating afferents that in turn modulate spinal circuits, FES-mediated effects on spasticity are largely due to muscle contraction and its targeting of the spastic muscle (i.e., agonist/antagonist) [23].

Therefore, FES electrically activates multiple muscles in a coordinated and sequenced manner via nerve fibers to produce a specific function [24]. The FES system generates a sequence of electrical stimuli that trigger action potentials in intact peripheral nerves, which further activate muscle contractions [25].

Based on these premises, it is relevant to consider the importance of innovation in technological therapeutic resources such as photobiomodulation and electrical stimulation, which may be configured as a new therapeutic possibility and/or adjuvant in the treatment of disc radiculopathy due to disc herniation, and may reduce the time of sessions and rehabilitation compared to traditional physiotherapy. Thus, the objective of this case study was to report the synergistic effects of the combined treatment of photobiomodulation and electrical stimulation, regarding the pain, sensorimotor function, degree of functional disability and quality of life in a patient with a medical diagnosis of lumbar radiculopathy due to disc herniation.

Methodology

The study was carried out after approval of the Research Ethics Committee (CEP) involved Seres Humans of the Santa Casa of Mercy of São Carlos, CAAE: 70562523.2.0000.8148.

The treatment was carried out at the Photodynamic Therapy Unit of Santa Casa (UTF) in São Carlos, a clinical research unit in partnership with the Institute of Physics of São Carlos, University of São Paulo, Brazil

The equipment was patented, Process number BR 10 2025 001000 3, which was developed by the Institute of Physics of São Carlos and allows the transmission of electrical stimuli from one electrode to another, associated with 4 light emitters (two with a wavelength in the red range at 660nm (V) and two with a wavelength in the infrared range at 808nm (IR), which radiate perpendicularly to the surface of the skin, with overlapping of these resources (Figure 1). The protocol consisted of 10 treatment sessions, twice a week, lasting 30 minutes each, synergistically using 660nm and 808nm therapeutic laser (100mW) and FES, which are electrical pulse envelopes for muscle contractions and will be used by a balanced asymmetric biphasic pulsed current, frequency of 30 pulses per second, pulse duration time, 300 microseconds, T-on of 15 seconds, T-off of 10 seconds, rise of 2 seconds, decay of 2 seconds, pulse amplitude according to the tolerance of each individual. The application region was directed both for the anatomical projection area of the vertebral segment and along the corresponding myotome (quadriceps muscle and fibular muscle).

For pain assessment, the Visual Analogue Scale (VAS) was used, and changes in the condition of execution of movements were analyzed using goniometric analysis, through the measurement of joint angles (goniometer). In addition, the Fugl-Meyer scale, the Roland-Morris and Short Form 36 (SF-36) questionnaires were applied.

Pain is a subjective symptom, which was assessed using the visual analogue scale (VAS), an easy and quick scale to apply, ranging from 0 to 10, with "0" referring to the absence of pain and "10" the maximum level of pain reported by the patient, which was asked to the volunteer during the assessment and reassessment.

Changes in the condition of execution of movements were analyzed through goniometric analysis, through the measurement of joint angles (ROM), related to flexion movements (ROM variation from 0 to 95 degrees), extension (ROM variation from 0 to 35 degrees), right and left lateral flexion (ROM variation from 0 to 40 degrees), right and left rotation (ROM variation from 0 to 35 degrees) of the lumbar spine.

Regarding the Roland-Morris Disability Questionnaire (QIRM) [26], which has a score of zero points (no disability) to 24 points (maximum disability), the higher the score the worse the perception of functional disability, with scores above 14 indicating severe disability of the individual in relation to chronic low back pain.

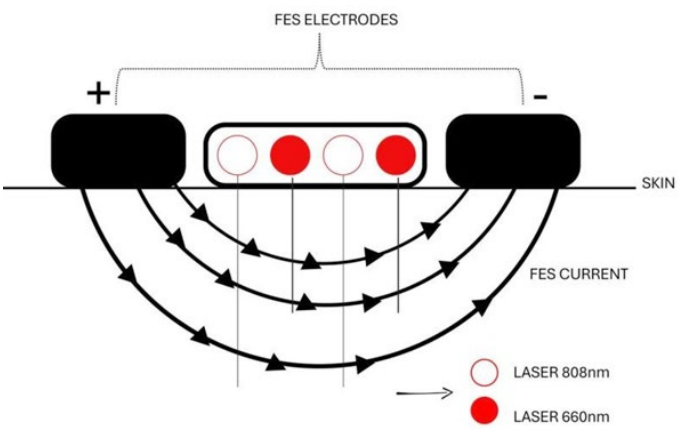

Figure 1: Illustration of the overlap of therapeutic fields promoted by functional electrical stimulation (FES) and Low-Level Laser Therapy.

Another scale used in this case study was the Fugl-Meyer Scale (EFM), for sensorimotor measurement [27], a clinical and research assessment instrument that is easy to apply and very frequently used. The numerical scoring system is cumulative, on a three-point ordinal scale applied to each item: 0 - cannot be performed, 1 - partially performed and 2 - completely performed.

This scale analyzes the development of motor function of the lower limbs, coordination/speed, passive movement of the joint, sensitivity and pain of patients.

Quality of life was analyzed using the SF-36 questionnaire [28], containing a total of 36 questions, composed of eight domains: functional capacity, physical aspects, pain, general health status, vitality, social aspects, emotional aspect and mental health. The score ranges from 0 to 100 (0 = worst health status; 100 = best health status).

Case Report and Results

Patient B.D., female, 29 years old, medical report reporting herniated disc in L5-S1. She presents with radiating low back pain in the left lower limb, antalgic posture, decreased strength in the left lower limb and functional limitations for more than three months.

The treatment performed was the synergistic use of Functional Electrical Stimulation (FES) and Laser (V/IV) in the regions of the L5-S1 myotomes, for 30 minutes (10 sessions; twice a week).

The evaluation identified a greater limitation in the ROM of the left side, which presented an increase in the ROM after treatment, observed in flexion (from 25 degrees in the pre-treatment to 85 obtained after treatment), in extension an increase from 20 to 30 degrees of ROM, in left lateral flexion (from 5 to 30 degrees) and right from 10 to 35 degrees of ROM. Furthermore, in the rotation movement to the left in the pre-treatment from 5 to 30 degrees after treatment, in rotation to the right (from 10 to 35 degrees of ROM). Therefore, all movements of the lumbar spine after treatment presented an increase in ROM (Figure 2).

Figure 3 shows the results of the VAS scale before and after the intervention, in which the lumbar low back pain from 8 to 0, with no pain after the treatment.

Associated with chronic low back pain, it was identified by the QIRM questionnaire, in which it was found that before treatment the score was (17) showing severe functional incapacity, and immediately after intervention with the proposed protocol the score decreased to (8), illustrated in (Figure 4).

It was evaluated by the EFM scale, corresponding to the increase in scores for the domains motor function of the lower limbs from 12 to 28 points, coordination/speed from 3 to 6 points, sensitivity with an increase from 9 to 12 points, values referring to passive movement of the joint from 10 to 20 and pain of patients went from 0.2 before treatment to 20 points after treatment, and these changes can be observed for each domain before and after the proposed protocol, illustrated in (Figure 5).

Regarding quality of life, the scores for the domains functional capacity, physical aspects, pain, general health status, vitality, social aspects, emotional aspects and mental health can be seen in (Table 1).

It can be seen that the greatest difference between the reassessment and the assessment (Δ) was for the vitality domain (Δ = 60), followed by general health status, functional capacity, pain and mental health with Δ of 55 points, while for the limitation domains related to physical and emotional aspects the Δ was 50 points, finally the lowest score was for the social aspects domain Δ of 30 points. Therefore, there was an increase in all domains of the SF-36 questionnaire after treatment.

Discussion

Currently, among the physiotherapeutic resources used to treat the limitations and symptoms of disc herniation, those based on the action of therapeutic laser or electrical stimulation, applied separately to ensure hypoesthesia or analgesia, locally or systemically [29].

The new equipment designed, developed and patented by the Physics Institute of São Carlos, allows the transmission of electrical stimuli from one electrode to another by combining the application of therapeutic laser resources and electrical stimulation, allowing the synergy of these resources in simultaneous application [30].

Electrical stimulation can produce pain suppression by activating afferents through modulation of spinal inhibitory circuits (pain gate system), which in turn modulate spinal circuits [31]. The low back pain observed in this case report disappeared after treatment verified by VAS; this result has a positive impact, if we consider that low back pain

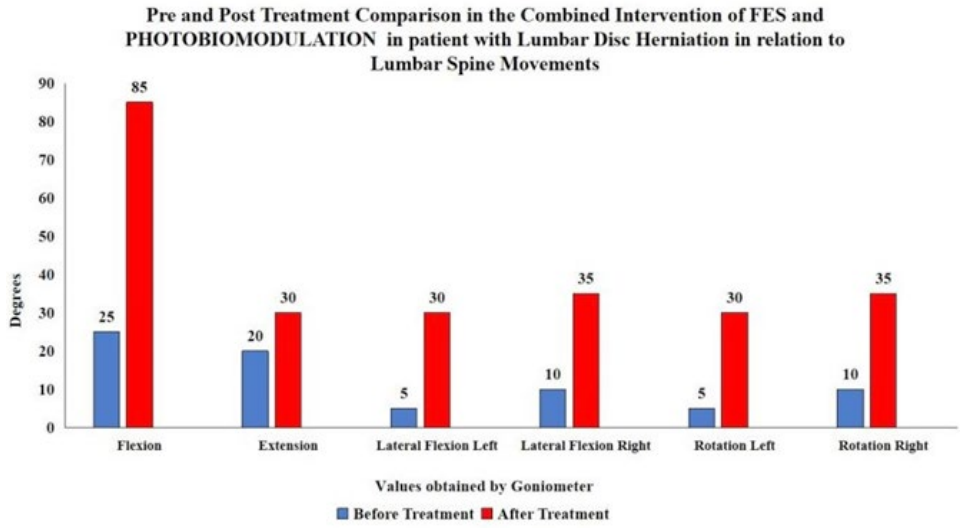

Figure 2: Degrees of range of motion for the lumbar spine pre- and post-treatment.

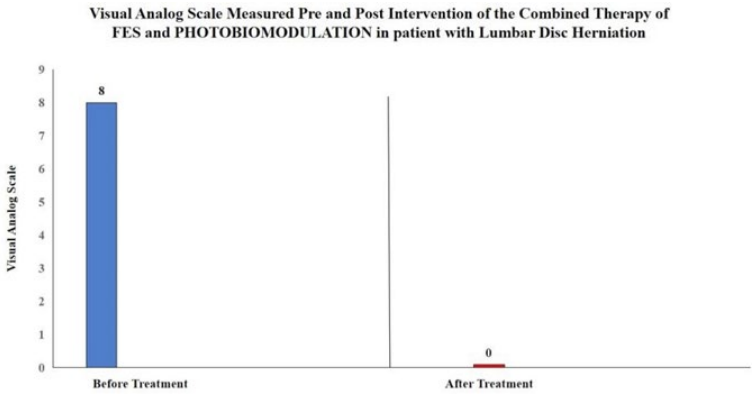

Figure 3: Pain assessment using the Visual Analogue Scale before and after treatment.

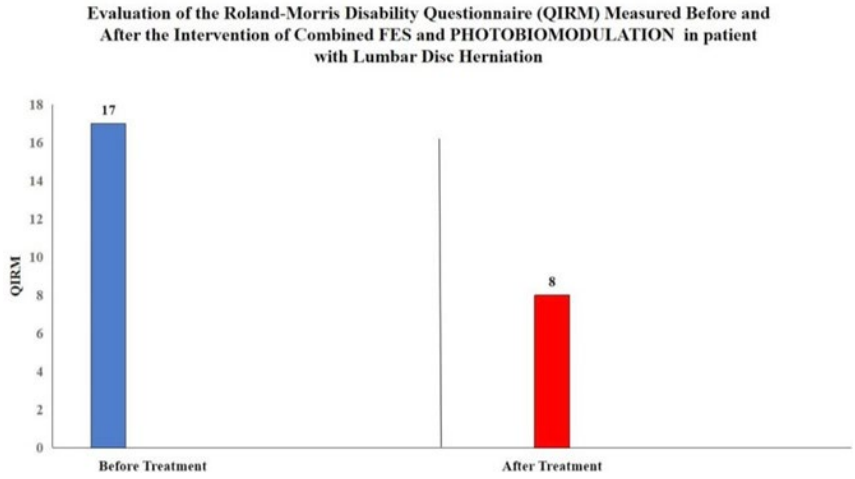

Figure 4: Roland-Morris Disability Questionnaire (RMQ), assessing the degree of disability of individuals with low back pain.

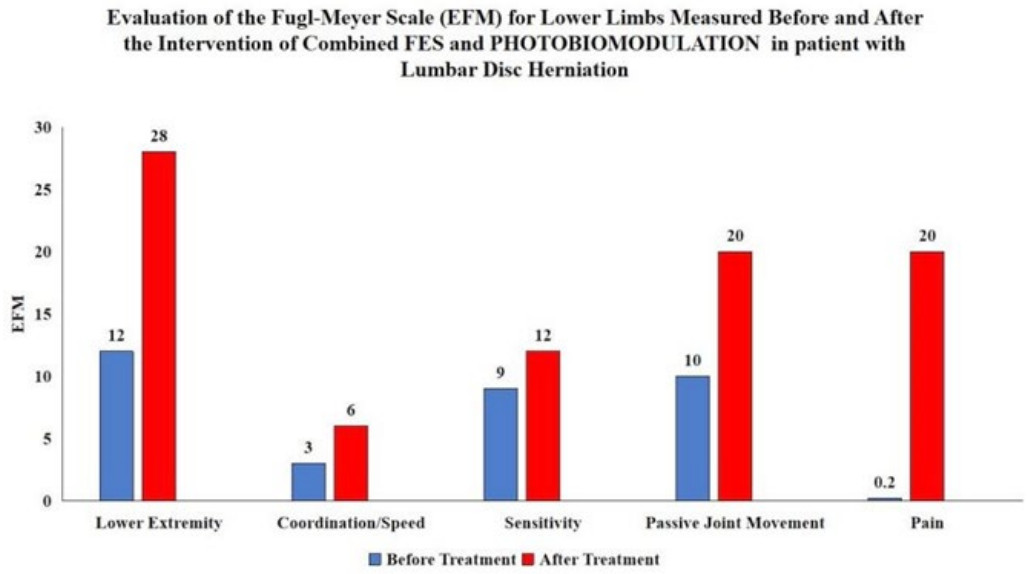

Figure 5: Fugl-Meyer Scale (EFM) for assessments of sensorimotor functions.

Evaluation of the SF-36 Questionnaire Mesuared Before and After Intervention	Pre-treatment	Post-treatment
Functional Capacity	25	80
Limitation by Physical Aspects	30	80
Pain	15	70
General Health Status	15	70
Vitality	20	80
Social Aspects	50	80
Limitation due the Emotional Aspects	30	80
Mental Health	20	75

Table 1: Scores of the SF-36 questionnaire domains pre- and post-treatment in a patient with lumbar disc herniation.

and sciatica have disabling and chronic characteristics, in addition to being the main symptom frequently observed in radiculopathies [32].

Also regarding pain, this clinical finding is in agreement with studies that highlight the analgesic effects of low-intensity laser, especially due to its ability to modulate nociceptive sensitivity by altering the excitation and nerve conduction of peripheral neurons, promoting the release of endogenous opioids and increasing the production of serotonin [33, 34].

Furthermore, the reduction in pain intensity caused by low-intensity laser therapy can be explained by the modulation of inflammatory processes, by reducing the release of pro-inflammatory cytokines and stimulating anti-inflammatory cytokines [35], in addition to antioxidant changes due to changes in redox metabolism resulting from increased ATP production [36]. With a greater amount of energy, cellular functions become more efficient and can adapt to stimuli more quickly and effectively [37]. As in this study, we promoted electrical stimuli associated with light, we suggest that molecular and cellular changes may possibly occur that influence pain and nerve transmission mechanisms [38].

In this case study, we found an association between VAS and QRMD related to the reduction of low back pain, which led to a transition from a condition of severe disability to low functional limitation. It is suggested that these results may have a positive impact on the patient's daily functionality. In the studies by Cairns et al (2006), an improvement in functionality, reduction of pain and improvement in the physical component of quality of life were observed after physiotherapy sessions in patients with recurrent low back pain [39].

Another aspect observed in this case study was that the patient had limited movement in the lumbar spine, especially the left one. It was observed that after treatment there was an increase in ROM, allowing greater execution of movements, results observed in the work developed by Rampazo et al (2024) in which the combination of photobiomodulation and TENS improved the intensity of pain during movement and local hyperalgesia in patients with chronic neck pain [40].

The improvement in mobility may be related to the sensorimotor function assessed by the EFM in all domains; there was an increase in scores, evidencing the improvement in the motor function of the lower limbs, coordination/speed, passive movement of the joint, sensitivity and pain of the patients. According to Shan et al (2023), they observed that after treatment with acupuncture there was an improvement in the EFM score and a decrease in the VAS, which impacted functionality [41].

In addition, the SF-36 quality of life questionnaire revealed that the treatment had a notable impact on increasing the participants' energy and disposition [42] This may be attributed to the use of laser therapy, which, in addition to reducing pain as evidenced by the VAS and inflammation, has shown, in previous studies [43, 44], positive psychological effects, such as increased motivation and disposition [45]. These effects may be explained by the fact that patients felt more comfortable and less limited [46]. The observed increase in energy may be a reflection of the pain relief and improved cellular function, allowing individuals to feel less fatigued and more capable of carrying out their daily activities with greater vigor and vitality.

Conclusion

In this case study, it can be observed that the patient with lumbar radiculopathy due to disc herniation benefited from the synergistic action of the treatment with overlapping fields between Transcutaneous Electrical Nerve Stimulation and Photobiomodulation, obtaining a reduction in low back pain, leading to a better execution of lumbar spine movements, impacting mobility and functionality, consequently, an optimization of sensorimotor function and quality of life. Thus, the new equipment proved to be a safe non-invasive resource, without side effects and with a viable application time in clinical practice, reducing the time of sessions and traditional physiotherapy treatment.

This way, it is believed that the new equipment leads to the sum of the physiological effects promoted by both laser and electrostimulation; however, further studies are necessary.

Conflict of Interest

The authors declare no conflict of interest.

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